

Watershed Modeling Approach To Assessing the Hydrologic Effects of Future Development in the Ninemile Creek Basin, Onondaga County, New York

Urbanization can alter the hydrology of a watershed, particularly the magnitude and frequency of storm-related flooding. Quantifying changes in streamflow that result from urbanization are critical for planning and designing bridges, culverts, stormwater-drainage systems, detention basins, and other stormwater-management facilities. Because data on storm-runoff volume and floodflow in specific areas are commonly unavailable, and future changes in these flow characteristics that result from urbanization cannot be measured directly, planners and engineers have come to rely on computerized models for this information.

The Town of Camillus, a suburb of Syracuse, N.Y., like many suburban communities, has undergone recent growth and is expecting continued residential and commercial development. Concern over the hydrologic effects of future development has prompted efforts to assess the likelihood that (1) flooding of Ninemile Creek in parts of Camillus will increase as the amount of pervious surface area available for infiltration decreases, and (2) the use of stormwater-detention basins to mitigate flooding could worsen flooding whenever the peak outflow from a basin coincides with the peak discharge in the receiving stream, thereby producing a larger peak discharge than would occur otherwise. In 1996, the U.S. Geological Survey, in cooperation with the Town of Camillus, developed a precipitation-runoff model representing a

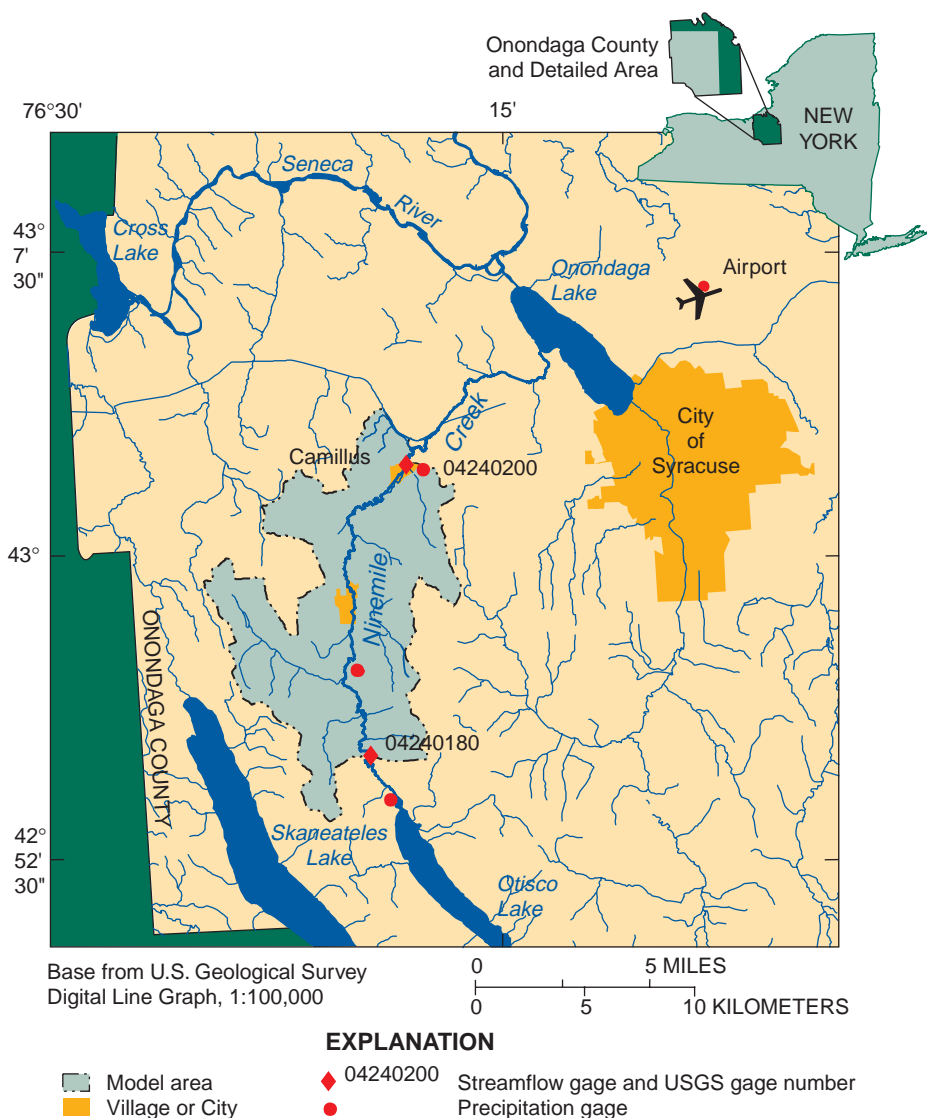


Figure 1. Principal geographic features of Onondaga County, N.Y., and location of the Ninemile Creek watershed model area.

41.7-mi² part of the Ninemile Creek watershed (fig. 1) to assess the timing and magnitude of peak discharges that could result from future development and the use of stormwater-detention basins. This fact sheet describes the results of the model simulations.

Model Selection

Several hydrologic simulations models are available that offer a range of functionality and options. Selection of an appropriate model requires an assessment of the project objectives and the characteristics of the watershed that is being simulated. The model chosen for the 1996-98 study of the Ninemile Creek watershed was the HSPF (Hydrological Simulation Program Fortran), release

11, developed by the U.S. Environmental Protection Agency (Bicknell and others, 1993). This model can incorporate several hydrologic features of the watershed that were considered important, including (1) extensive wetlands, (2) ground-water flow to the carbonate bedrock, and (3) snowmelt runoff; the model also can simulate water quality if desired in the future.

Model Development and Calibration

A Geographic Information System (GIS) was used to compile spatial data on watershed soils, land use, slope, surficial geology, and bedrock geology. This information was simplified and combined to obtain 14 hydrologic response units

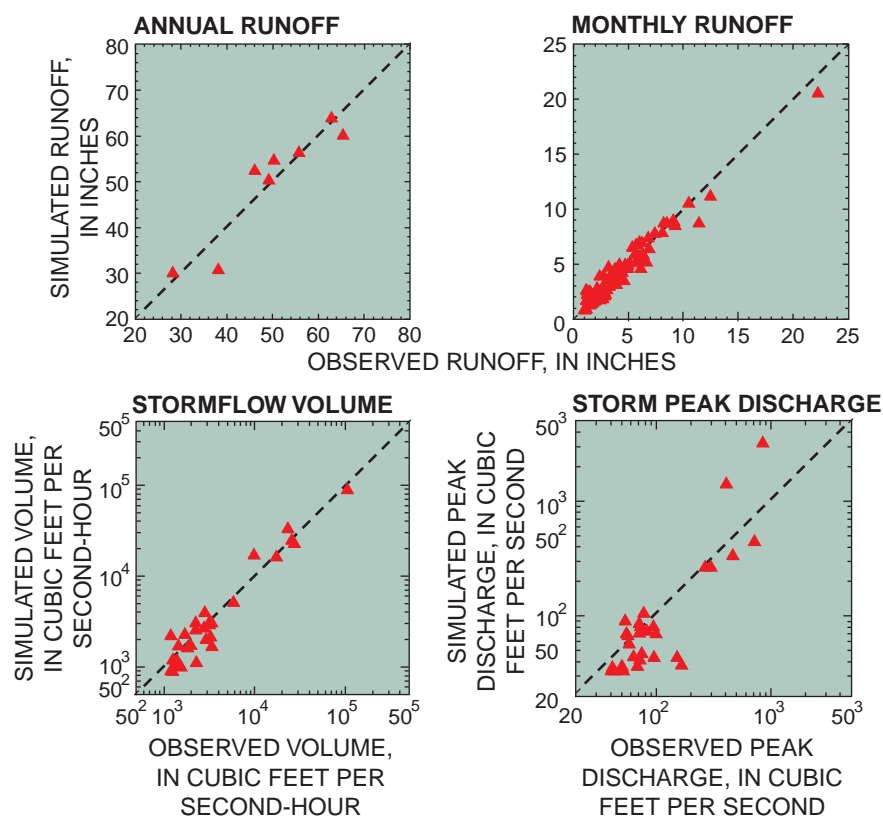


Figure 2. Simulated runoff, volume, and discharge of Ninemile Creek at Camillus, Onondaga County, N.Y., in relation to observed values, water years 1988-96.

(HRU's), each of which represents a unique combination of land use, slope, infiltration rate, and water-storage characteristics.

Calibration, a critical step in the development of any simulation model, is the process of comparing simulated streamflows with observed streamflows over a range of conditions, then adjusting the values assigned to the model variables until the discrepancies are minimized. Through the calibration process, model errors are calculated, and their effect on the simulation results are evaluated. Uncalibrated or poorly calibrated models can produce erroneous or misleading information and could result in poor planning or engineering decisions. The correlations between simulated and observed annual and monthly runoff for water years 1989-96 (October 1, 1988 through

September 30, 1996) and between simulated and observed stormflow volumes and peak discharges for 30 non-winter storms in the Ninemile Creek watershed are depicted in figure 2.

The annual maximum peak discharge in this area typically results from combined rainfall and snowmelt. For example, rain and snowmelt in January 1996 produced one of the highest recorded peak flows (2,530 ft³/s) on Ninemile Creek at Camillus (fig. 3B); this discharge occurs on average once every 15 years. This storm also produced the highest mean daily discharge recorded at the Camillus stream gaging station (1,690 ft³/s) since the station began operation in 1958. The simulated values for this 3-day storm (January 18-20, 1996) were within 3 percent of the observed peak discharge and within 10 percent of the runoff volume (fig. 3).

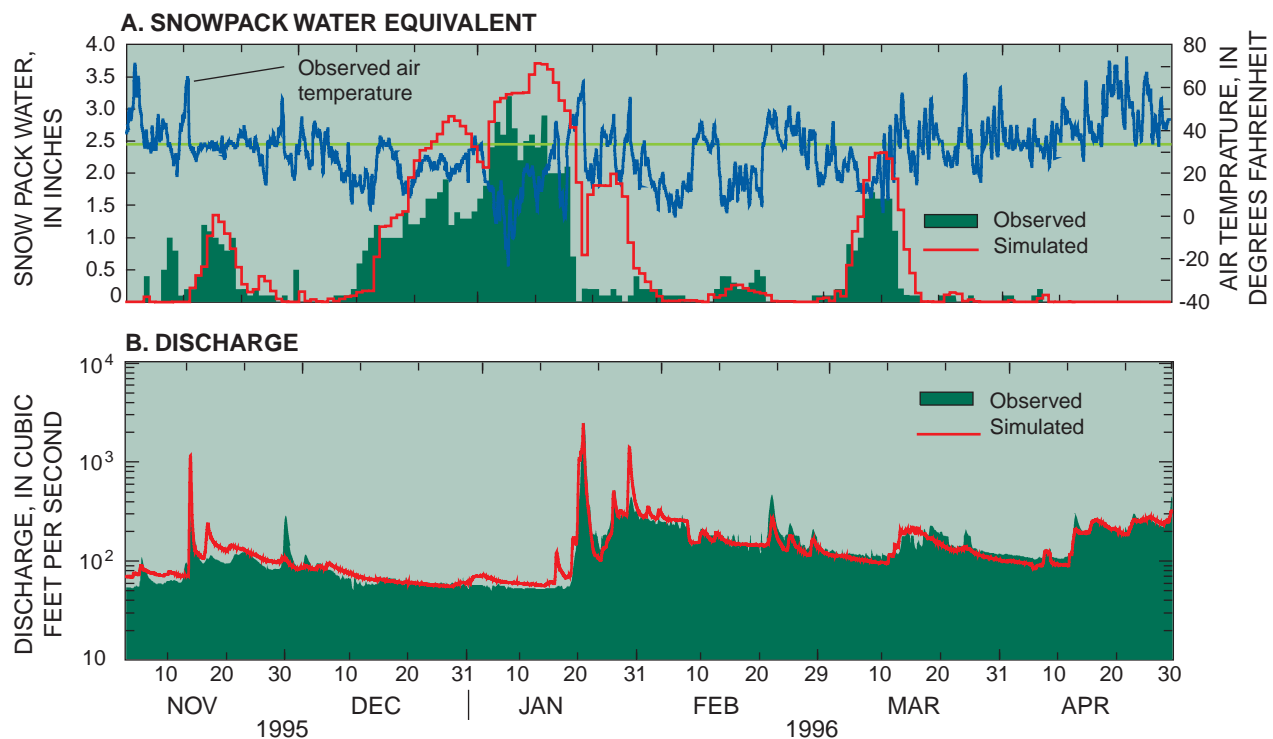


Figure 3. Winter runoff and snowpack buildup and melt at Camillus, N.Y., 1995-96: (A) Simulated and observed snow-pack water equivalent. and (B) Simulated and observed discharge of Ninemile Creek

Effects of Future Development

Possible future development in the Ninemile Creek watershed was represented in the model in two ways: (1) as an “open/residential” area that simulates runoff from mixed pervious and impervious areas that drain to pervious areas, or (2) as an impervious area that drains directly to stream channels. Under present-day conditions, about 7 percent of the modeled area is developed, about 0.4 percent of which is impervious land that drains directly to stream channels. An additional 60 percent of the modeled area is developable (referred to as “100-percent buildup” herein). Under this condition about 7 percent of the model area is considered impervious. The simulations of potential development reflects current land-use zoning restrictions and represents only the areas that

are suitable for development; for example, steep slopes and wetlands were excluded.

Runoff after future development will probably reflect the increase in open/residential and impervious lands. The most effective way to represent these factors in the model is uncertain because future drainage patterns are unknown, but comparing the simulated hydrologic effects of development as open/residential land with the effects of development as impervious land provides an indication of the watershed’s probable response to future development. Examples of the simulated watershed response to spring and summer storms under the two types of buildup are plotted in figure 4 and summarized in table 1.

The simulated effects of both types of development were most pronounced in the summer, when soil-

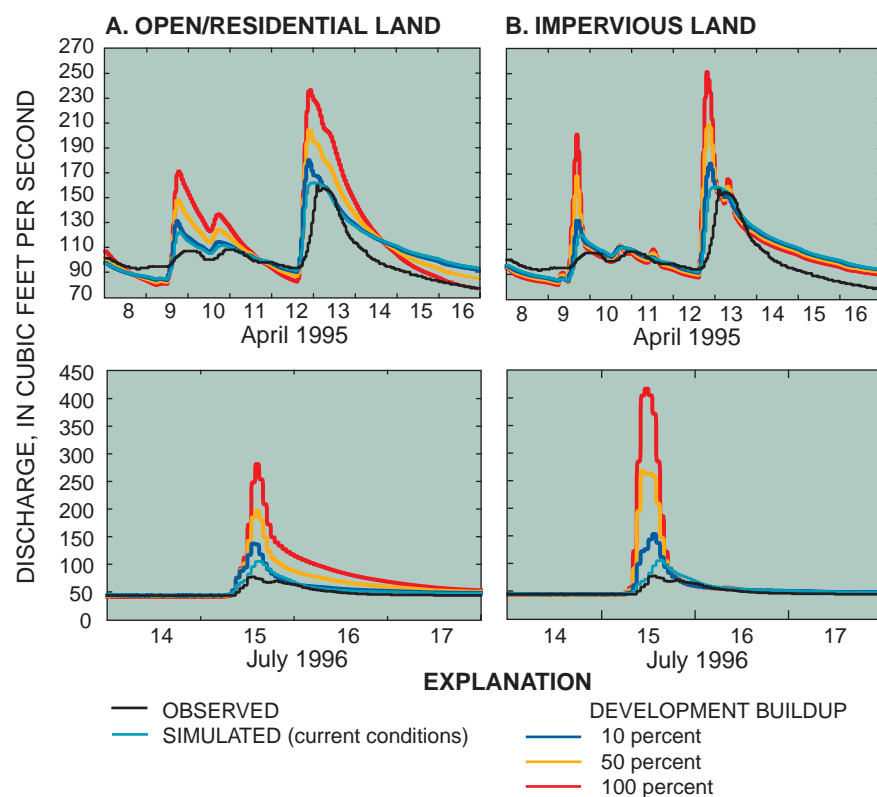


Table 1. Predicted increases in discharge in Ninemile Creek at Camillus, N.Y., resulting from future development as open/residential land and as impervious land.

Percent Buildup	Average percent increase in non-winter stormflow	
	Peak discharge ¹	Runoff volume
A. Buildup as Open/Residential Land		
10	10	1.4
50	22	5.8
100	37	11
B. Buildup as Impervious Land		
10	13	2.1
50	38	7.5
100	68	13

¹ Average increases in relation to calibrated values for 30 non-winter 1995-96

Figure 4. Observed and predicted spring and summer stormflows of Ninemile Creek at Camillus, N.Y. under present conditions and with future development at 10-, 50-, and 100-percent buildup, represented in two ways: A. As open/residential land, and B. As impervious land.

water storage is low, and infiltration occurs readily in pervious areas. Precipitation during other times of the year, when soil-water storage is near capacity (because evapotranspiration is low), does not infiltrate and produces mostly surface flow; thus, the effects of increased impervious-surface area are smaller during these seasons than in the summer. Increases in peak discharge from large storms were also less than the increases resulting from small storms (fig. 5) because large storms deplete soil-water storage and produce mostly surface flow.

A comparison of log-Pearson Type-III probability curves (a method used to estimate the magnitude and frequency of floodflows) for simulations of development as impervious land indicated that the increase in peak discharge was about the same for storms of all magnitudes. Thus, the relative effect of

increased urbanization diminishes with increasing peak discharge. Analyses of peak discharges for the 1989-96 water years indicate that, under 100-percent buildup as impervious land, stormflows that now occur on average once every 2 years will occur once every 1.5 years, and stormflows that now occur on average once every 5 years will occur once every 3.3 years. Future development is not expected to cause significant increases in flooding along Ninemile Creek during large-magnitude storms but is expected to increase the frequency and magnitude of flows resulting from small storms. These simulations also indicated a slight decrease in discharge of 3-day low flows.

Urbanization also affects three components of runoff— baseflow (sustained ground-water flow), interflow (fast-responding ground-water flow), and surface flow, as indicated in figure 6 for simulations

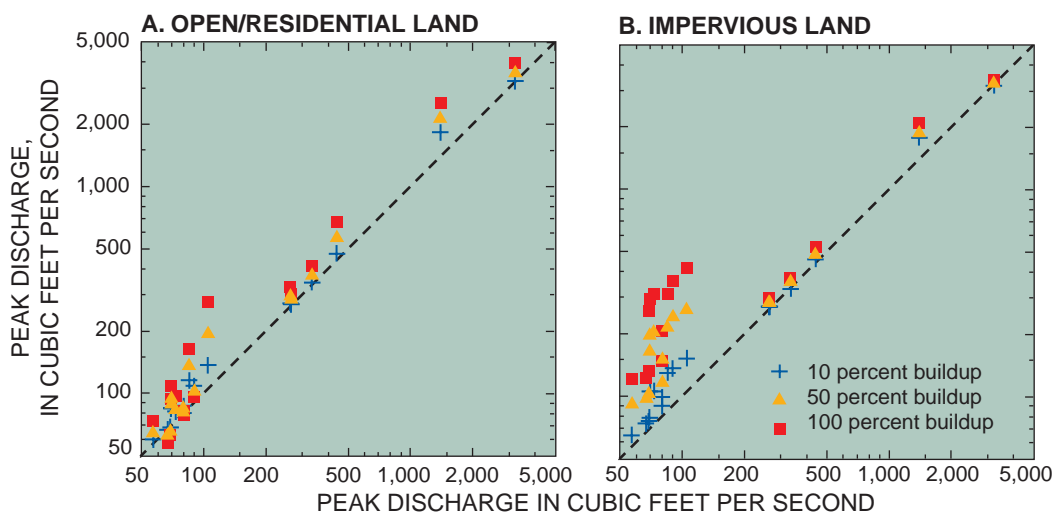


Figure 5. Simulated 1995-96 peak stormflow of Ninemile Creek at Camillus, N.Y., based on future development at 10-, 50-, and 100-percent buildup as: A. Open/residential land. B. Impervious land.

of the July 15, 1996 storm. Baseflow was only slightly lower in impervious-land simulations (0.116 in.) than in open/residential-land simulations (0.118 in.). This small difference is attributed to the relatively small area (about 7 percent of the watershed) that would be affected with 100-percent buildup as impervious land; the decrease in baseflow would probably be larger, however, in subbasins that have a relatively large percent increase in impervious area. Interflow was 74 percent smaller in impervious-land simulations (0.029 in.) than in open/residential-land simulations (0.111 in.), and surface runoff was about 165 percent greater in impervious-land simulations (0.114 in.) than in open/residential-land simulations (0.043 in.). Accordingly, the peak discharges in impervious-land simulations were larger, and the response to precipitation more rapid, than in open/residential-land simulations. Flow component differences between the two types of simulations diminished as soil-water storage approached capacity.

Effects of Detention Basins

Stormwater-detention basins are commonly used in developing areas to attenuate peak discharges and to control nonpoint-source pollutants. The predicted effects of a detention basin depend on (1) the storage-to-discharge characteristics, (2) the inflow magnitude relative to available storage, and (3) outflow magnitude relative to flow in the receiving stream.

Model simulation of the effect of a basin serving a hypothetical 147-acre moderate-density development adjacent to Ninemile Creek at Camillus indicate that, the basin outflow would exceed the uncontrolled flow that would occur if the basin were absent (fig. 7) for a period after the peak discharge in Ninemile Creek. During this period, the difference between the detention-basin outflow and uncontrolled flow is less than 1 percent relative to flow in Ninemile Creek at Camillus. Simulation results for a hypothetical detention basin with half the original storage capacity indicated that the difference between basin outflow

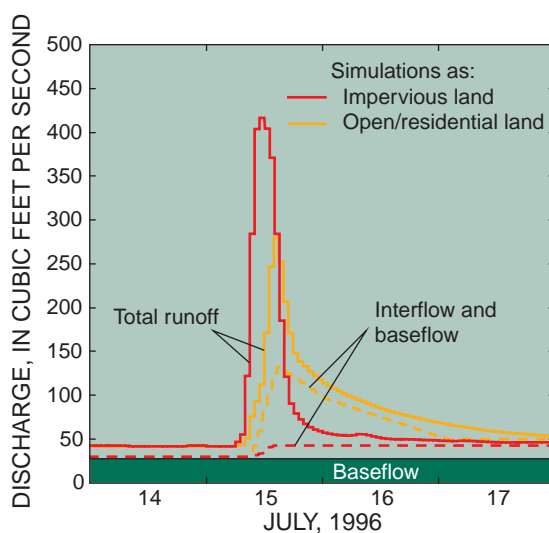


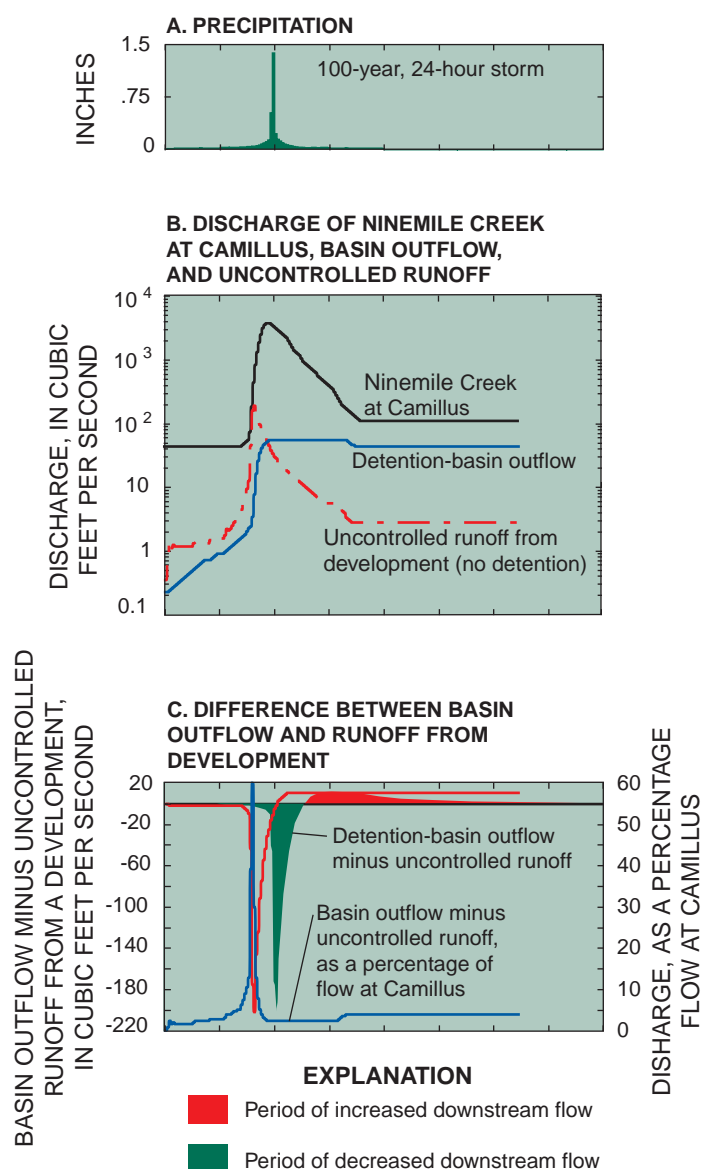
Figure 6. Simulated runoff components of Ninemile Creek at Camillus, N.Y. for the July 15, 1996 storm, for buildup represented as open/residential land and as impervious land.

and uncontrolled flow would be about twice as large as with the full-size basin. Additionally, the maximum difference between basin outflow and uncontrolled runoff would occur closer to the time of peak discharge in Ninemile Creek. As a result, the smaller basin would contribute about 2 percent more flow to Ninemile Creek at Camillus near the time of the peak

than would uncontrolled runoff from the development. Although the increases in peak discharge that would result from the coincidence of peak basin outflow with the peak flow in Ninemile Creek are small, the increases in peak discharge could be cumulative as new development increase and stormwater controls are added.

Many parts of the watershed that are expected to undergo development drain to streams tributary to Ninemile Creek; channel storage along these tributaries, particularly those with extensive wetlands, will decrease and delay peak discharge. Simulations of a detention basin that drains to a tributary, rather than directly to Ninemile Creek, indicated no increase in peak discharge at Camillus under any flow conditions. The peak outflow from the detention basin occurred long enough after the peak discharge in the tributary that the peak flows in Ninemile Creek for storms of all magnitudes were decreased.

Runoff from the simulated development, which drains to a tributary, would significantly increase the peak discharge in the tributary in the absence of a detention basin. The simulated peak discharge in a tributary for a 2-year storm was more than twice the peak discharge under current (undeveloped) conditions, and the simulated peak from a 100-year storm was about a third larger. Adding a detention basin decreased the peak discharge of the tributary to about the same as that under predevelopment conditions.



Future Model Applications

The watershed model can help planners and engineers examine the complexities of runoff and, thus, support comprehensive stormwater management decisions in the Ninemile Creek watershed. Ninemile Creek is believed to be a major source of total phosphorus to Onondaga Lake (Moffa and others, 1994). Water quality simulations can be added to the model to help address the magnitude, source, and control of non-point pollution to Onondaga Lake.

by Phillip J. Zarriello

Figure 7. Predicted flows in Ninemile Creek watershed, Onondaga County, N.Y., resulting from a 100-year, 24-hour storm at a hypothetical 147-acre residential development with and without a stormwater-detention basin .

Selected References

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